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FABRICATION, SPIN TESTING AND MAGNETIC TESTING OF A WELDED ROTOR IN A 36 000 RPM LUNDELL ALTERNATOR

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This information is being published in preliminary form in order to expedite its early release.

ABSTRACT

A Lundell-type rotor consisting of magnetic and nonmagnetic materials was fabricated by puddle welding Inconel 625 between two sections of AISI 4617 steel. The finish-machined rotor which has a major diameter of 3.26 inches (8.28 cm) was spin tested to 50,000 rpm (140% of design). No measurable yield occurred. Test results showing saturation curves for load and no-load conditions with the rotor installed in a 1200-hertz Brayton-cycle research alternator are presented.

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SUMMARY

A Lundell-type rotor consisting of magnetic and nonmagnetic materials was fabricated by puddle welding Inconel 625 between two sections of AISI 4617 steel. The finish-machined rotor which has a major diameter of 3.26 inches (8.28 cm) was spin tested to 50,000 rpm (140 percent of design speed). No measurable yield occurred. Test results showing saturation curves for load and no-load conditions with the rotor installed in a 1200-hertz Brayton-cycle research alternator are presented.

INTRODUCTION

A Brayton-cycle space power system being tested at the NASA Lewis Research Center has a 1200-hertz Lundell alternator. The rotor (fig. 1) for this alternator consists of two separate magnetic sections with north poles on one section and south poles on the other section. A third section between the two magnetic sections consists of a nonmagnetic metal. These three sections are bonded together by brazing (ref. 1). Spin testing such a brazed rotor to failure (ref. 2) revealed that the failure occurred in the braze area.

In an attempt to develop an alternate method of fabricating this type of rotor, Inconel 625 (ref. 3) was puddle welded between two sections of AISI 4617 steel. The objective was to meet the magnetic requirements with weldable materials that could be subjected to high rotational stresses. A secondary objective was to develop a method of fabrication that might be applicable to similar rotors in future space power systems.

DESCRIPTION OF ALTERNATOR AND ROTOR

The 1200-hertz Brayton-cycle research alternator is a three-phase 120/208-volt machine. Rated output at 36,000 rpm is 14.3 kilovolt-amperes with a 0.75 lagging power factor (ref. 4). For the test results presented in this report, all the alternator field coils were connected in series. The brazed rotor for this alternator has magnetic sections consisting of AISI 4340 steel separated by a nonmagnetic section of Inconel 718.

Magnetic AISI 4617 steel and nonmagnetic Inconel 625 were selected for the welded rotor. These materials are weldable, and AISI 4617 steel has a lower magnetic resistance (reluctance) than AISI 4340 steel. During welding, Inconel 625 is less crack sensitive than Inconel 718.

ROTOR FABRICATION

The cross-sectional area of the magnetic section of the rotor varies axially. Templates were made which duplicated these cross-sectional areas at several axial locations. The templates were then attached to a common base at intervals equal to the rotor-axial-location intervals. The spaces between the templates were filled with a plastic material to form a mold with a smoothly varying contour from template to template. Using this mold as a duplicating guide, the contour was machined into two AISI 4617 steel billets (figs. 2 and 3).

The nonmagnetic section was fabricated by puddle welding uncoated Inconel 625 wire on the two machined billets by the tungsten-inert-gas (TIG) welding method (figs. 4 and 5). This puddle-welding build-up of the Inconel 625 was continued until the required distance between the two magnetic sections was established (fig. 6) and the gap completely filled. Periodic ultrasonic and Zyglo inspections were made of the welds to check for cracks. The completed billet was then heat treated at 1150° F (621° C) for one hour and finish machined to the final configuration. Finish machining included a 0.50 inch (1.27 cm)-diameter center hole drilled through the length of the rotor. Additional ultrasonic and Zyglo inspections were made after final machining.

DISCUSSION OF RESULTS

Spin Testing

Spin testing for ten minutes at 50,000 rpm in a vacuum was accomplished by suspending the rotor from an air turbine (fig. 7). A lower catcher bearing with a tapered bore was mounted below the shaft in case the turbine spindle failed. A journal catcher bearing with a 0.12 inch (.30 cm) diametral clearance was mounted at the upper end of the suspended rotor. Speed was monitored by a magnetic pickup at the turbine. At 50,000 rpm, the calculated stress level was about double the calculated 22,900 pounds per square inch (15,800 N/cm^2) at 36,000 rpm. Micrometer measurements of the outside diameters before and after spin testing revealed no yielding.

Magnetic Testing

Saturation curves for open circuit and for three-phase short circuit are shown in figure 8. Data for the three-phase short circuit were taken by applying a balanced three-phase fault at the alternator terminals.

Load saturation curves are shown in figure 9. For the design point of 120 volts, the welded rotor required a field excitation of 1850 ampere-turns at unity power factor and 2150 ampere-turns at 0.75 power factor. In comparison, the original brazed rotor (ref. 4) required a field excitation of 2,000 ampere-turns at unity power factor and 2500 ampere turns at 0.75 power factor. The puddle-welded rotor is thus not only strong enough but also more than adequate magnetically.

SUMMARY OF RESULTS

As an alternative to brazing AISI 4340 and Inconel 718 for a Lundell-type rotor, a rotor was fabricated by puddle welding nonmagnetic Inconel 625 between two sections of magnetic AISI 4617 steel. Spin testing this welded rotor to 50,000 rpm produced no measurable yielding.

Not only is the puddle-welded rotor sufficiently strong but the rotor's magnetic characteristics exceeded those of the original brazed rotor.

Lewis Research Center
National Aeronautics and Space Administration
Cleveland, Ohio, August 31, 1971

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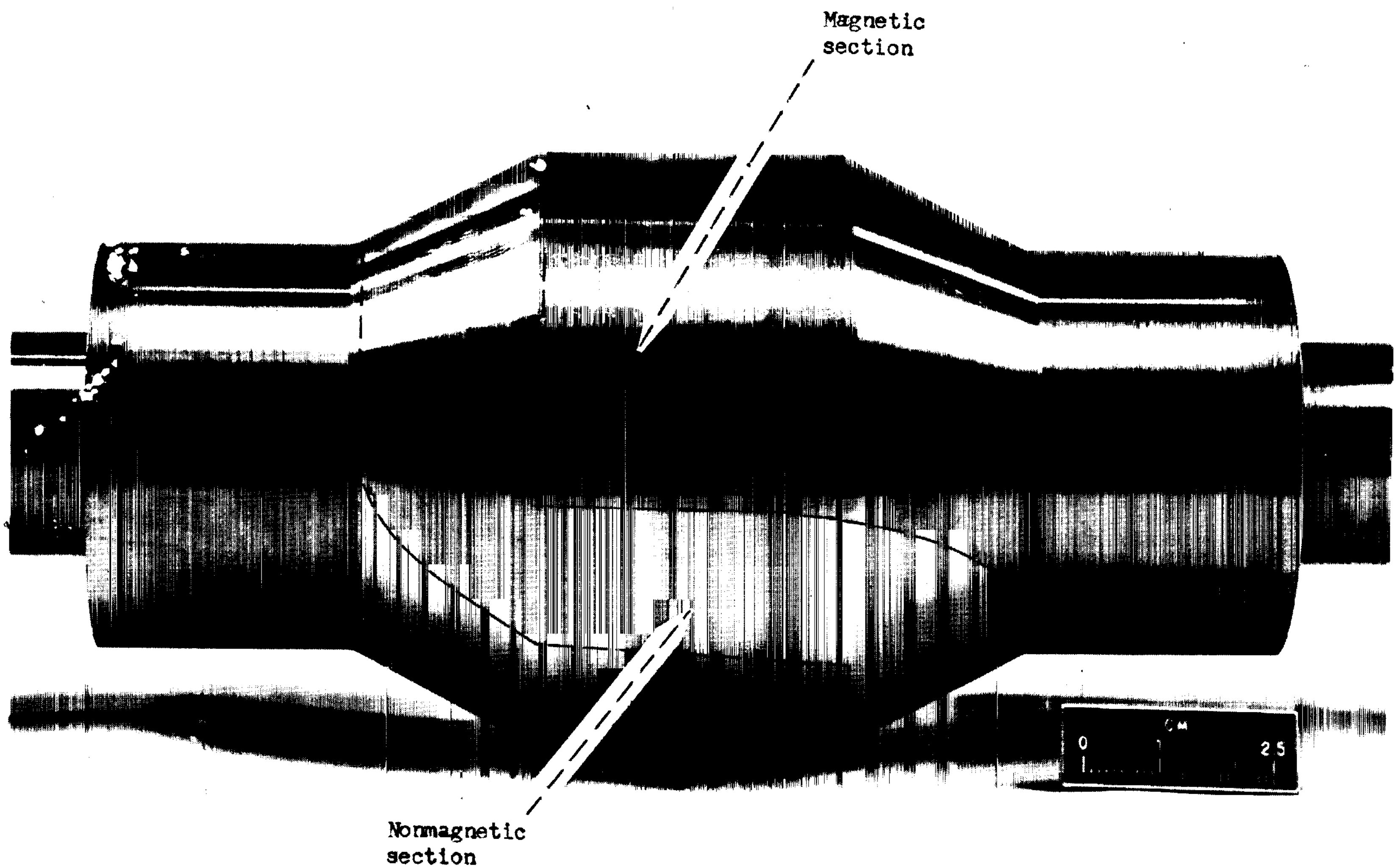

Figure 1. -Alternator rotor

Figure 2. - Machined billet of AISI 4617

Figure 3. - Machined billets of AISI 4617

Figure 4. - Machined billet with deposited Inconel 625

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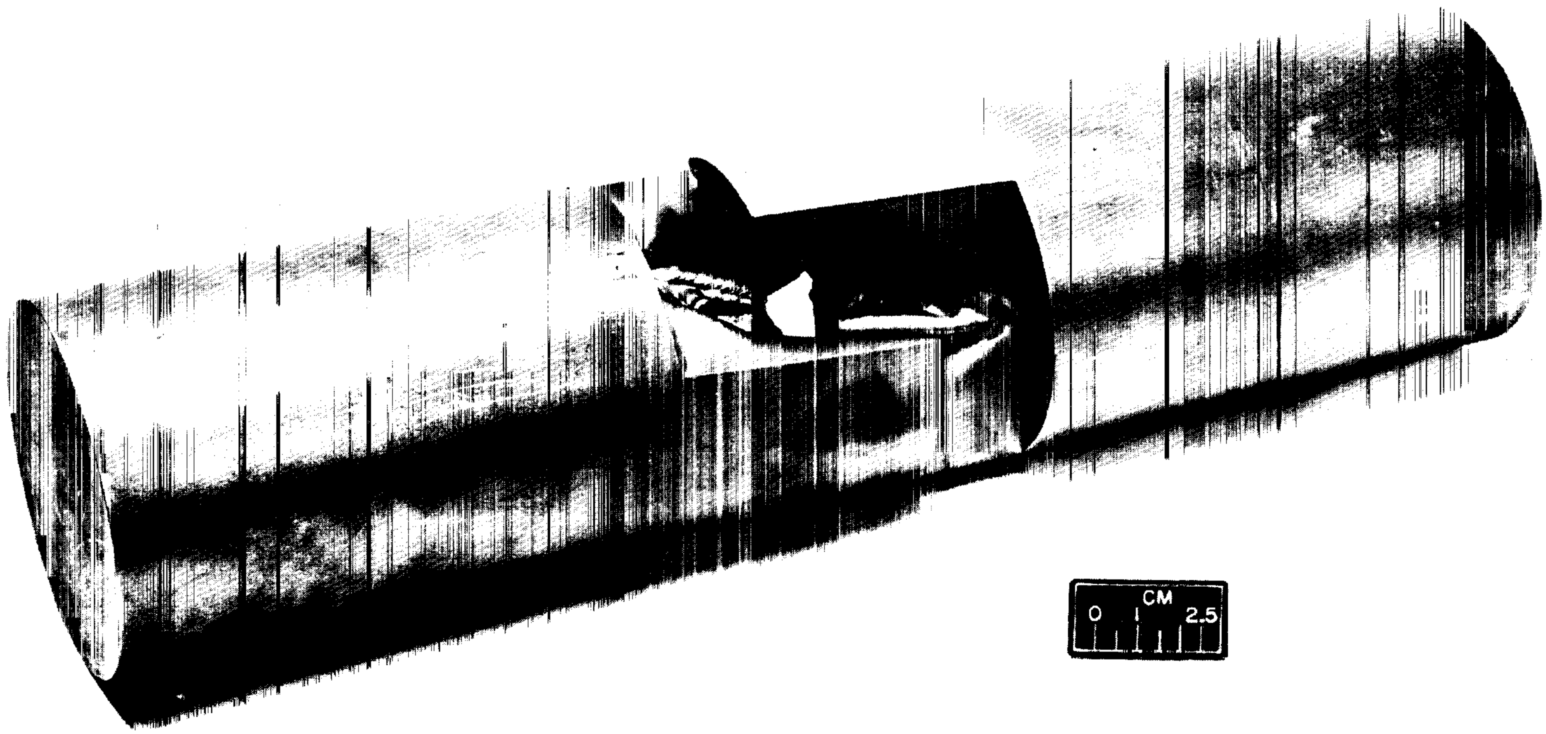

Figure 5. - Machined billets with deposited Inconel 625

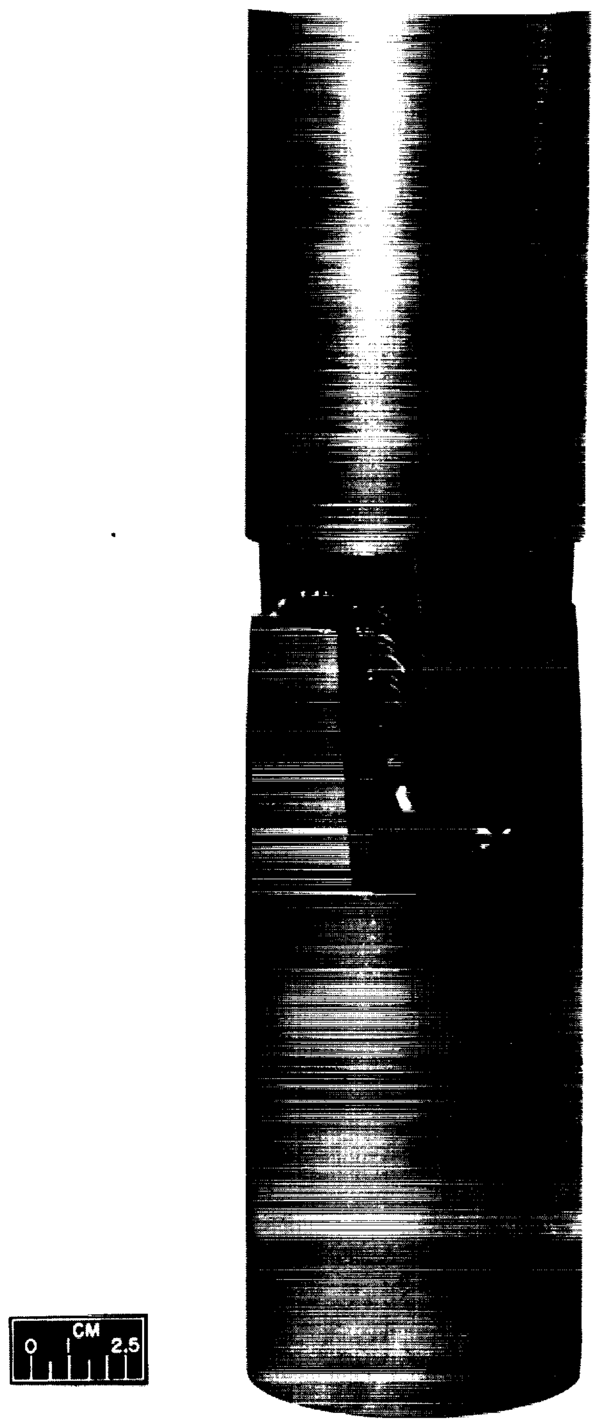

Figure 6. - AISI 4617 billets joined by Inconel 625

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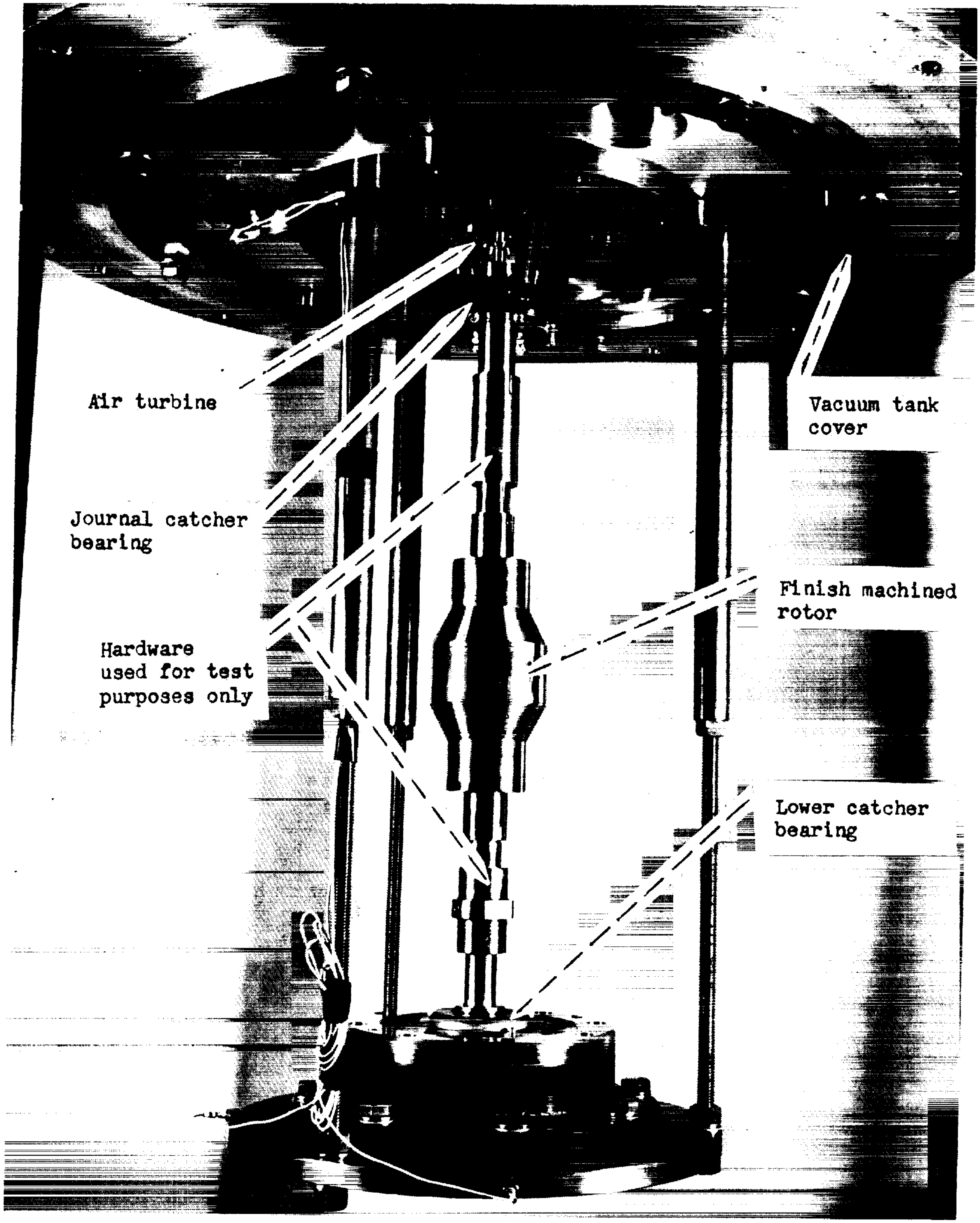

Figure 7. - Spin test assembly

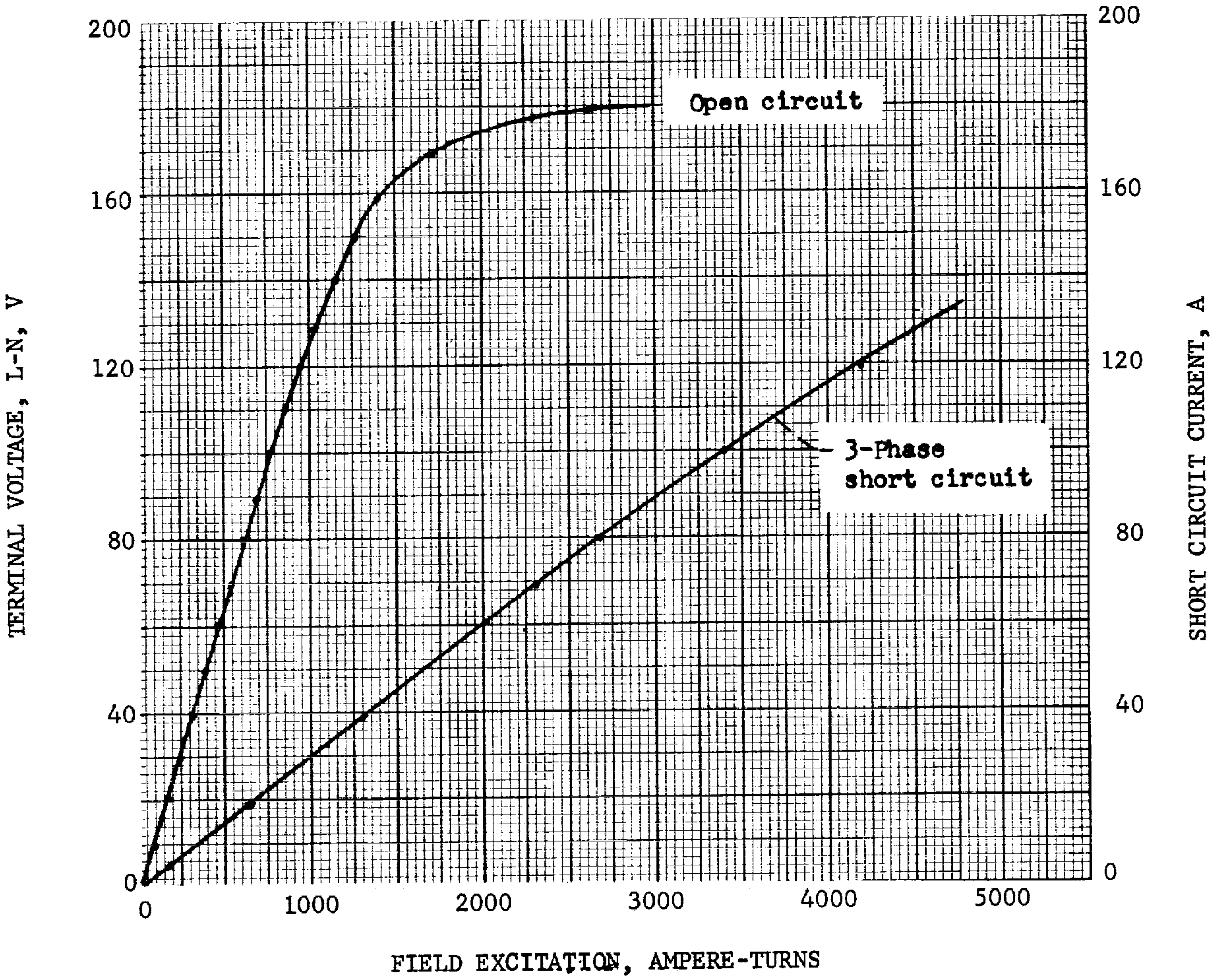

Figure 8 - No Load Saturation Curves for 1200 Hertz Lundell Alternator with Welded Rotor

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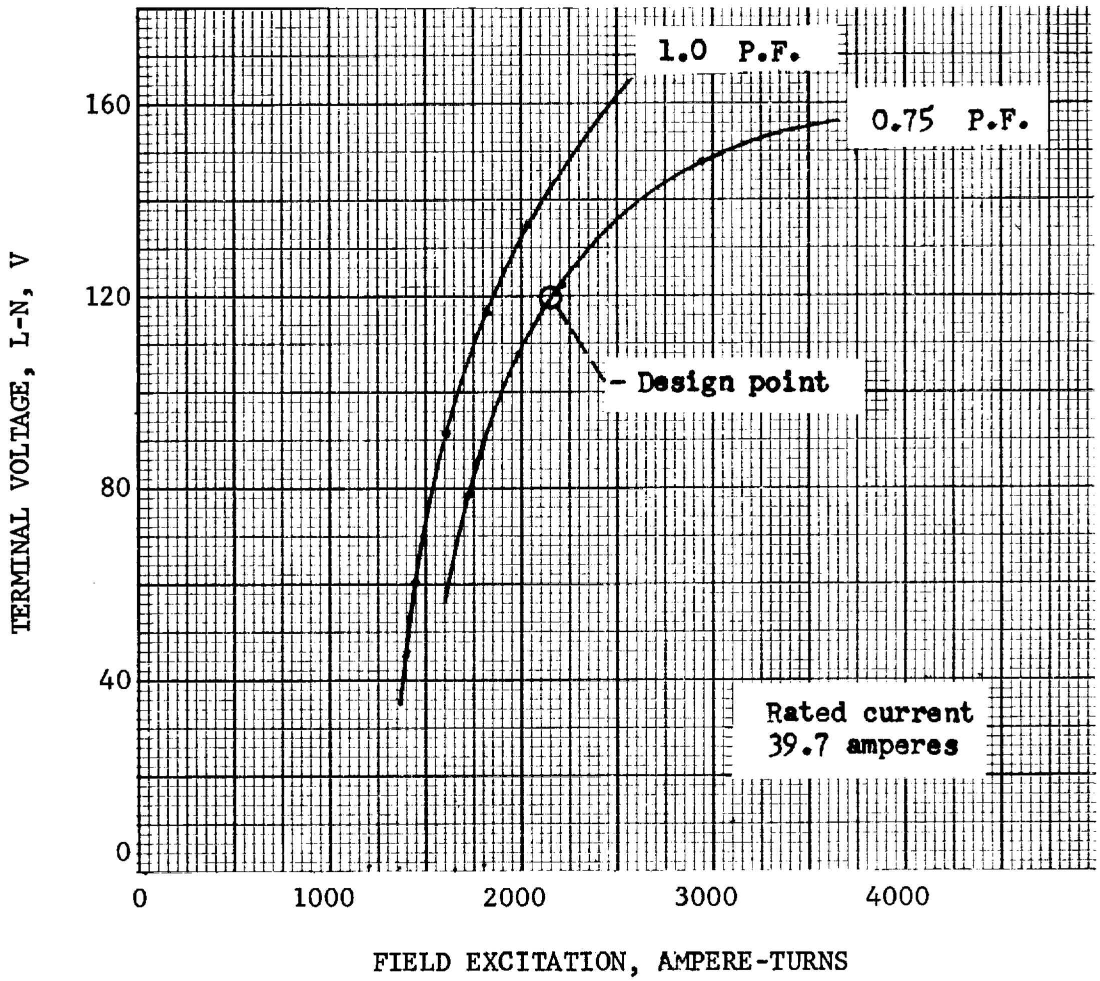

Figure 9 - Load Saturation Curves for 1200 Hertz Lundell Alternator with Welded Rotor